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SOILS INVESTIGATION

PROPOSED APARTMENT COMPLEX

WAIPIO, OAHU, HAWAII

FOR

KALANI GARDENS, INC.

# 335

4108 GP

DAMES & MOORE NO. 7503-002-11

WITHDRAWN  
MUNICIPAL REFERENCE RECORDS CENTER  
City & County of Honolulu  
City Hall Annex 158 S. King Street  
Honolulu, Hawaii 96813



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2875 SOUTH KING STREET · HONOLULU, HAWAII 96814 · (808) 946-1455  
CABLE: DAMEMORE · TELEX: 63-4100

PARTNER: DAVID C. LIU  
ASSOCIATE: JAMES R. SWAISGOOD  
CHIEF ENGINEER: HOWARD A. SCHIRMER

March 2, 1970

Kalani Gardens, Inc.  
195 South King Street  
Honolulu, Hawaii 96813

Attention: Mr. Journ T. Yee

Gentlemen:

Ten copies of our report, "Soils Investigation, Proposed Apartment Complex, Waipio, Oahu, Hawaii, for Kalani Gardens, Inc." are herewith submitted.

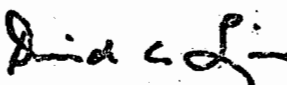
The scope of our work was defined in our proposal dated January 30, 1970. We anticipate some additional work on this project involving review of final plans and correspondence with FHA.

Preliminary findings were discussed with your architect, engineer, and personnel from your organization as they became available.

If you have any questions on any portion of this report, please contact us at any time.

Yours very truly,

DAMES & MOORE

  
David C. Liu

DCL RHW js

SOILS INVESTIGATION  
PROPOSED APARTMENT COMPLEX  
WAIPIO, OAHU, HAWAII  
FOR  
KALANI GARDENS, INC.

SUMMARY

Our investigation revealed conditions that we believe to be suitable for the planned development. Buildings may be supported on shallow footings and the natural slopes should remain stable through the life of the structure. Recommended foundation, earthwork and set-back criteria are contained in the report along with suggested construction procedures that we feel will assist in avoiding the introduction of undesirable conditions. We anticipate reviewing your final plans.

INTRODUCTION

This report presents the results of our soils investigation performed at the site of a proposed apartment complex in Waipio, Oahu, Hawaii. The general location of the site is shown on Plate 1, Map of Area. The topography of the site, the boring locations, and the proposed structure locations are shown on the Site Plan, Plate 2.

The purpose of this investigation was to develop design and construction criteria considered pertinent to the planned construction. In addition, every effort was made to meet the requirements of the Federal Housing Administration

and to provide information necessary for acceptance by FHA.

The specific scope of work included the following:

- 1) Drilling of test borings,
- 2) Inspection of existing surface conditions at the site,
- 3) Development of information and recommendations concerning the stability of the site and the planned structures,
- 4) Development of information pertinent to the construction at the site, including excavation and grading.

The results of our field exploration and laboratory testing and a detailed description of the methods and procedures employed are presented in the Appendix to this report.

#### PROJECT CONSIDERATIONS

The planned apartment complex involves the construction of six individual apartment buildings accompanied by one-story service structures and parking for approximately 151 vehicles. The locations and dimensions of the various planned structures are shown on Plate 2, Site Plan. The apartment buildings will be three and four stories high, as noted. It is our understanding that the buildings will be constructed of concrete blocks and that the parking lots will

be surfaced with flexible pavements.

The planned grading will involve removing material from above elevation 700 and using it to construct a level parking area southwest of the single four-story building. This grading will require the construction of two retaining walls, with the maximum fill height of 10 feet. The maximum cuts will be on the order of three feet except where existing spoil is to be removed. Drainage of the finished site will be generally to the southeast toward Kipapa Drive. It is also planned to grade several areas in the lower portions of the site for landscape and recreation purposes.

#### SITE CONDITIONS

##### SURFACE CONDITIONS

The most apparent surface condition within the confines of the site is the steep topography along the northwest boundary. The surface elevations vary considerably in this area, and slopes range up to 1:1 in local areas with some small slopes that are even steeper. Generally, slopes with angles greater than 40 degrees are barren while flatter slopes are covered with vegetation. Maximum slope heights approach 60 feet.

There are more large trees in the southern than the northern portion of the site, and numerous significantly sized trees are located near the crest of the aforementioned

steep slopes. Grasses and weeds mantle the entire site, their density appears to vary only at locations where the surface has been disturbed by earthwork or landscape operations.

Erosion has played a paramount role in the establishment of the existing site topography. It is reported that portions of the northwestern slopes were trimmed during the construction of the adjoining road and drainage canal, and that some spoil was dumped in the higher elevations. In all portions of the site, the topography generally produces drainage towards the steep slopes.

Several minor slump scarps were located by our geologist near elevation 680, as shown on the Site Plan. These scarps appeared to lie approximately perpendicular to the surface drainage and may be located primarily in fill material which was placed as spoil during the construction of Waipio Acres. It is planned that the scarps within the parking area will be removed prior to site grading.

#### SUBSURFACE CONDITIONS

Soil which has been alternately desiccated and saturated extends to approximately 20 to 30 feet below the ground surface at the site. The demarcation between the desiccated and undesiccated material is not abrupt but has a transition zone and appears to be at a lower elevation near

the steep slopes.

The soil which has been desiccated displays extremely high strengths, especially when its moisture content is below saturation, and fails in a brittle manner in the laboratory. The deeper soils are also relatively strong but fail in a manner which reveals a lower modulus of elasticity. The upper desiccated soils show a decrease in strength when saturated but remain stronger than the deeper, permanently saturated soils.

At depth, the weathering has not reduced the entire rock structure to soil. The borings drilled above the slopes did not encounter this soil-rock-transition zone; however, information from the borings located at the toe of the slopes indicates that this zone has its upper limits near elevation 635.

The ground water table was not encountered in our borings. The soils appeared to be generally saturated below elevation 670, but this situation is undoubtedly altered by seasonal rainfall variations.

#### DISCUSSIONS AND RECOMMENDATIONS

##### GENERAL

We have reviewed your grading plans transmitted to us on February 19, 1970, and have found them to be in general accordance with the recommendations contained herein.

However, we would appreciate the opportunity to work with you through the finalization of plans to assure that the necessary requirements are met.

Generally, the foundation soils at the site are of high strength and only moderately compressible near the surface but become somewhat weaker and more compressible with depth. Because of the considerations necessary for a complete appraisal of the subject site, we are presenting these considerations under separate headings in the remainder of this report.

#### SUBSURFACE CONDITIONS

The soils which underlie the site are a result of the weathering of basalt lava flows. This weathering is a complicated and somewhat undefined process; but, generally, the weathering becomes less complete with depth from the ground surface. However, this can be modified rather extensively by the variations in the amount of ground water which leaches through the material. Further complicating the process is the degree of desiccation in the upper soils. If the on-site soils are allowed to dry, there are forces introduced into the soil mass which produce a denser and stronger material. The degree and depth of desiccation is influenced by climate, vegetation cover, and by existing and past site topography.



Spheroidal weathering can produce boulders and boulder clusters within a soil mass, and it has been our experience that soils such as those under this site often display this characteristic. However, our borings did not indicate any large number of such formations. It appears that boulders will be less prevalent near the slopes.

There are several spoil piles in the higher areas of the site which are evidently composed of material that was "wasted" during the construction of Waipio Acres. It is planned that this local fill will be removed during grading of the site. We have been informed that spoil was also dumped in and along the existing swale near Boring 9. Test results indicate that the material encountered in Boring 9 possessed a lower density and thus support the aforementioned information. However, old small-scale topographic maps do not reveal any extensive changes in the surface contours since 1937, and we have concluded that the existing fill is relatively thin and has been in place a sufficient period of time to possess substantial strengths. The slumps mentioned earlier in this report appear to have occurred in this existing fill and probably are the result of erosion of the spoil and added loads due to saturation following periods of high rainfall.

### SLOPE STABILITY

Analyses were performed to evaluate the stability of the existing topography under the loads that will be imposed by the planned earthwork and construction. Engineering assumptions were made to reflect the most adverse foreseeable conditions, including total saturation of the soils, limited water-filled tension cracks, and earthquake loadings.

An average shear strength value was selected from the strength tests conducted on the deep, saturated soil. This strength was assumed to reflect the strength along any failure surface when the soils become saturated. Additionally, it was assumed that unclosed tension cracks, subjected to hydrostatic pressures, would extend as deep as ten feet below the existing ground surface. It should be pointed out that no tension cracks were observed at the site, and this assumption was in anticipation of some surface cracking during construction.

The most critical situation analyzed by us would be located near the highest portion of the parking lot retaining wall located west of the four-story apartment building. Based on the aforementioned assumptions, this slope would have a factor of safety of 1.7 when subjected to the planned loads.

To provide the necessary safety against undermining by erosional forces, we recommend that all structures be set back from the crest of steep slopes, and it is believed that

preliminary layout dated February 19, 1970, would satisfy this requirement. In addition, we believe that planting should be done at the level portion about the steep slopes in order to reduce seepage and erosion.

#### EARTHWORK

Prior to the mass earthwork at the site, any area to be cut or filled should be stripped of all surface material containing organic or deleterious material. This should amount to approximately 10 inches of the surface material. In general, disturbance to the existing topography and vegetation cover should be minimized, and stripping should be restricted to only those areas involved in site grading. The stripped surface materials could be stockpiled for later use as topsoil during planting of relatively level areas.

All fill placed within the site, except topsoil for planting, should be compacted to 90 percent of the maximum density as established by the Modified AASHO Procedure, Test Designation T-180. It will be very important to compact any fill slopes, and our recommendations for construction of fill slopes should be noted under the Construction Methods section of this report. A compaction curve for the on-site material is shown in the Appendix.

Fill slopes should be constructed at a ratio of 2:1

or flatter and cut slopes should not be constructed steeper than  $1\frac{1}{2}:1$ . It is believed that cut slopes of 2:1 have been used in the preliminary grading plan.

#### RETAINING WALLS

We have assumed that the material to be retained by the planned retaining structures will be on-site soils. It is our understanding that the only structural retaining wall required at the site will be to the west of the parking area for the four-story apartment building. For the design of this wall, we recommend that the lateral earth pressures be computed on the basis of an equivalent fluid weighing 45 pounds per cubic foot. Passive earth pressures in the natural materials can be evaluated by the use of an equivalent fluid weighing 200 pounds per cubic foot. Maximum toe pressures should not exceed 3,000 pounds per square foot.

It is recommended that the retaining wall be founded at the existing natural grade and the weight of the fill placed over the foundation be utilized to resist the overturning moment due to lateral earth pressures. It is also recommended that a shear key approximately one foot deep below the wall foundation be provided for resistance against sliding. This should be located near the interior edge of the foundation.

It is understood that surface water in the parking

area will be controlled by low curbs. Nevertheless, drainage of water from behind the wall should be provided by a blanket of clean sand, one foot thick, installed immediately behind the wall. Water collected in this drainage blanket should be drained off outside the walled area.

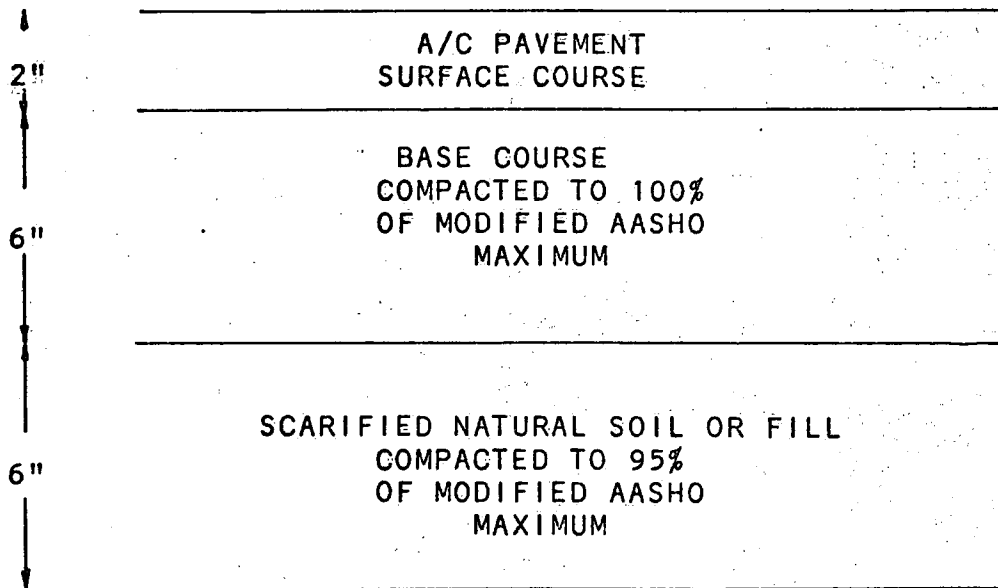
#### BUILDING FOUNDATIONS

All structures may be founded on shallow footings using a maximum bearing pressure of 4,000 pounds per square foot. Footings should be located at least 24 inches into natural material. They should have least dimensions of 16 inches and should be at least 4 inches wider than the wall that the footing is to support.

First floor slabs-on-grade will require minimum slab thicknesses of four inches. Beneath the slabs, a base course at least four inches thick and composed of material between one-quarter and two inches maximum dimensions will be required. Subgrades should be compacted to 95 percent of the aforementioned standard to a depth of six inches. A vapor barrier should also be provided beneath the slabs-on-grade.

#### PARKING PAVEMENTS

It is recommended that the following pavement section be used for parking lots at the subject site.



#### CONSTRUCTION METHODS

The control of surface drainage should be given primary consideration during construction. All surface water should be directed toward Kipapa Drive or into preconstructed drainage structures. It is suggested that the drainage channel planned near the parking lot retaining wall be built prior to stripping and that surface water be directed into this structure. Otherwise, the site could experience extensive erosion before the parking lot fill and retaining wall are completed.

Our experience with the soils at the site indicates that the compaction of these materials is extremely difficult except for large-scale grading operations. Thinner lifts may be necessary for the limited earthwork planned for this project. Also, it has been our experience that this material can be compacted much more readily if its moisture content is maintained a few percentage points above optimum.

It is important that foundation excavations do not unintentionally reduce the design set-backs. Therefore, the excavations for footings should be made vertically, and at no time should the excavation be dug horizontally from the slope.

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The following Plates and Appendix are attached and complete this report:

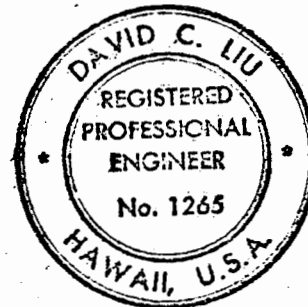
Plate 1	-	Map of Area
Plate 2	-	Site Plan
Appendix	-	Field Exploration and Laboratory Testing

Respectfully Submitted,

DAMES & MOORE

*David C. Liu*  
David C. Liu

DCL RHW js

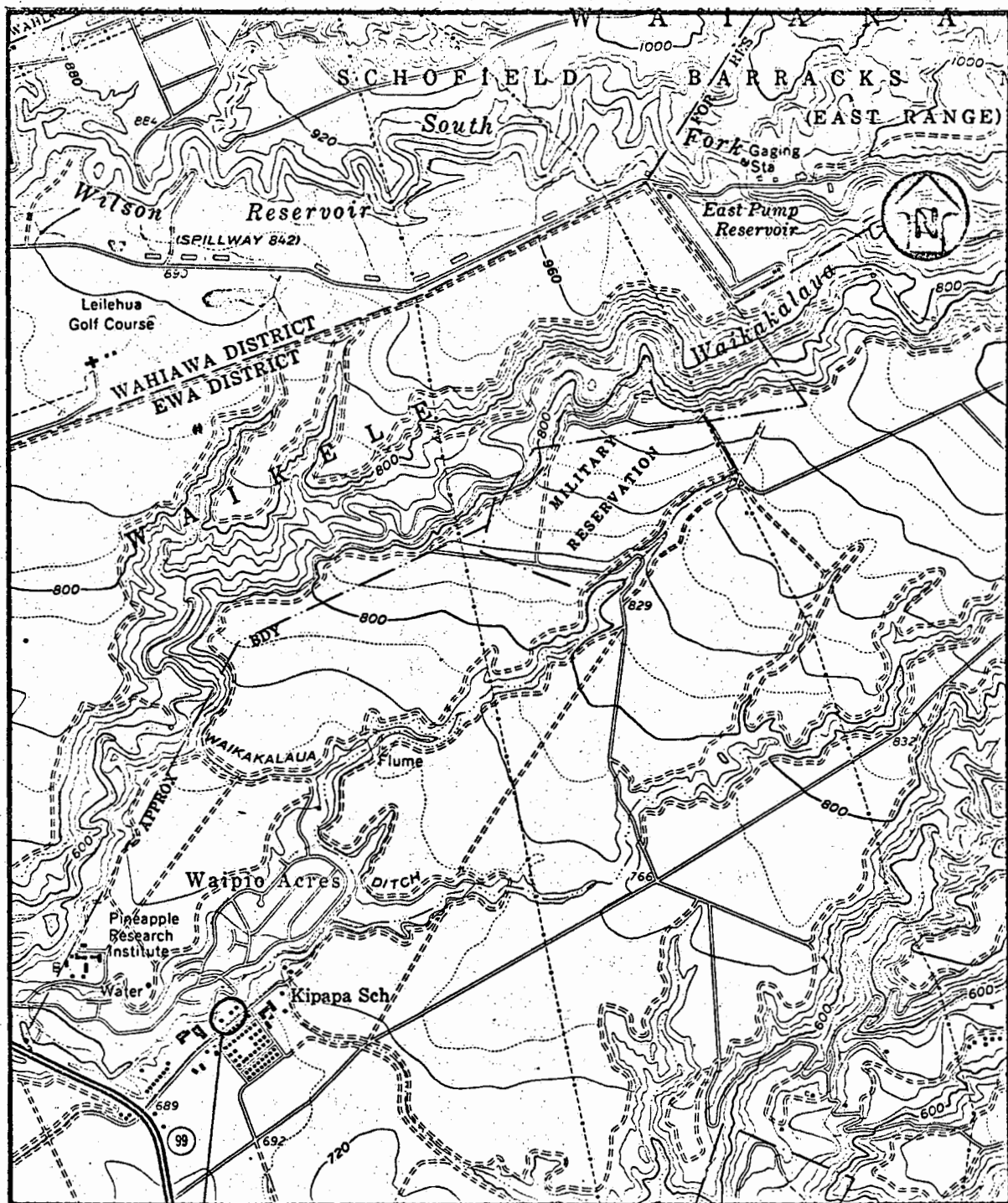


THIS WORK WAS PREPARED BY  
ME OR UNDER MY SUPERVISION.

*David C. Liu*



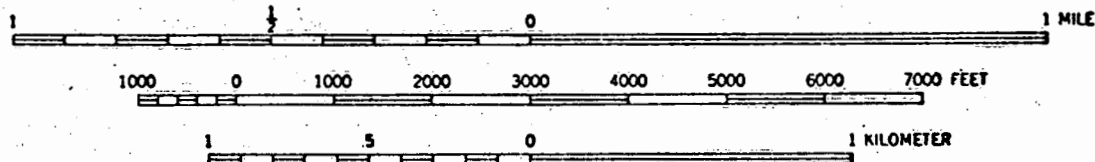
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GENERAL AREA SHOWN ON SITE PLAN

# MAP OF AREA

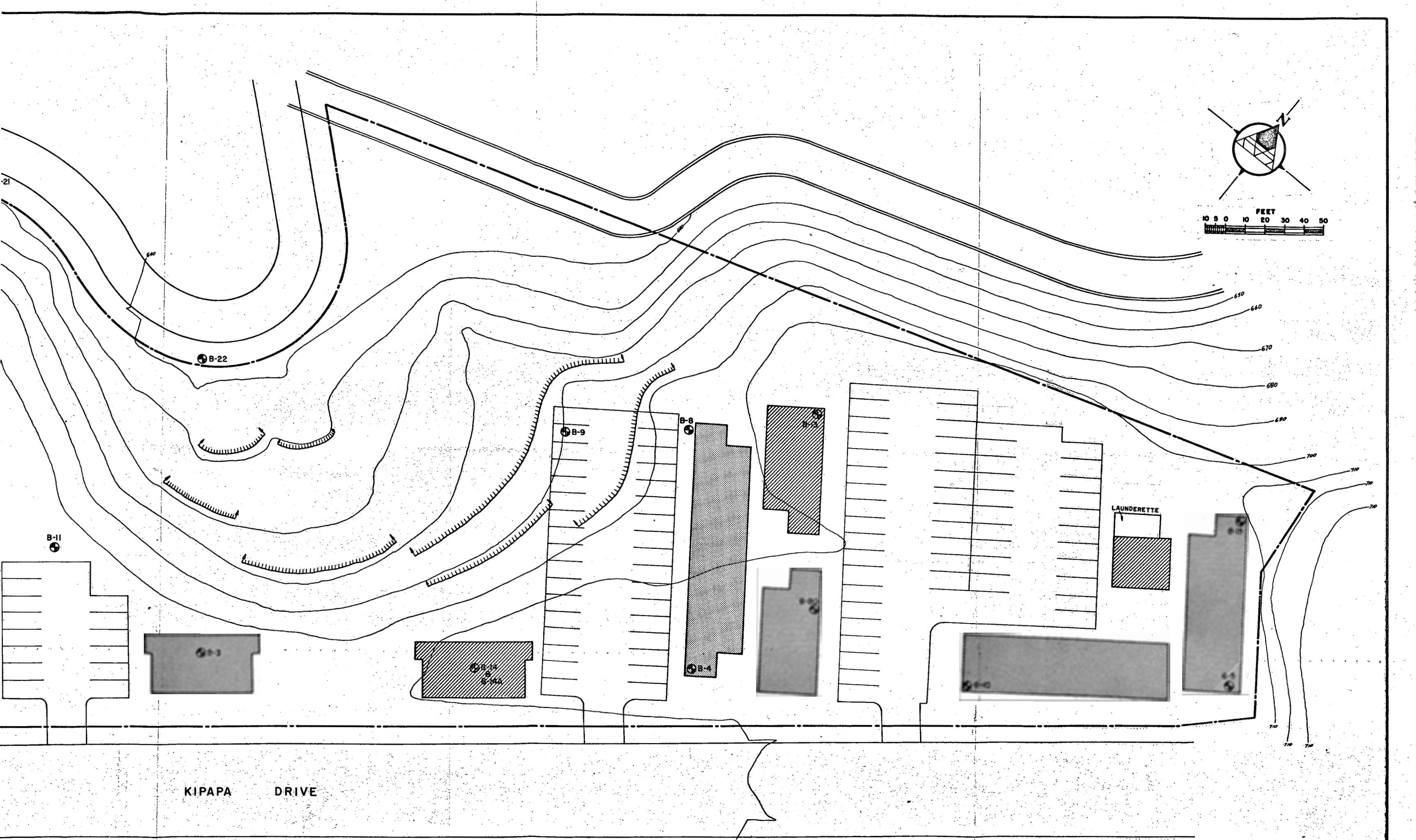
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REFERENCE:  
 U.S.G.S. QUADRANGLE MAP  
 WAIPAHU, OAHU, HAWAII  
 DATED 1959

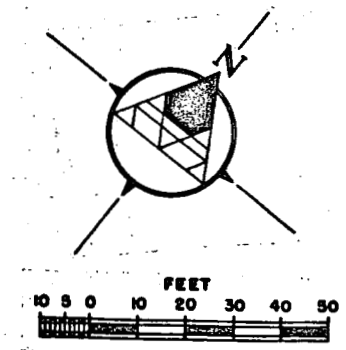
DAVID S. MOORE

PLATE 1



KIPAPA DRIVE

# SITE PLAN



- LEGEND:
- ⊕ DAMES & MOORE BORING
  - ▨ 3-STORY APARTMENT STRUCTURES
  - 4-STORY APARTMENT STRUCTURE
  - ▤ RELIC SLUMPS



REFERENCE:  
KALANI GARDEN APTS.  
WONG & WONG ASSOC.  
DATED: JANUARY 28, 1970

SITE PLAN

## APPENDIX

### FIELD EXPLORATION AND LABORATORY TESTING

#### FIELD EXPLORATION

To explore the subsurface conditions at the site, 23 borings were drilled to depths of between 10 and 50 feet below the ground surface at the locations shown on the Plot Plan in the body of this report. The logs of these borings are presented on Plates A-1A through A-1F, contained in this Appendix. Field explorations were carried out on February 2 through February 4, 1970. A general geologic reconnaissance of the area was conducted in addition to the test boring program and was designed to assist in the correlation of the boring information and to delineate any significant surface features which might influence our conclusions about the site.

Borings were advanced using two truck-mounted auger-type drill rigs under the direct supervision of two of our engineers. Our personnel maintained logs of the materials encountered in the borings and assisted in obtaining samples of the soils that were penetrated. The soils were classified in accordance with the Unified Soil Classification System, shown on Plate A-2. The equipment that was used to obtain the samples is shown on Exhibit A-1.

One of our geologists performed a site reconnaissance during which he attempted to map the surface features which

would provide information concerning the subsurface conditions at the site. Specifically, his work included locating and identifying any slides or slumps and erosional features. An attempt was made to evaluate the erosional characteristics of the slopes at the site by observing the undermining experienced by vegetation near their crests.

#### LABORATORY TESTING

Selected undisturbed samples were subjected to laboratory tests to determine their characteristics, including strength, compressibility, expansive properties, moisture contents and densities. Laboratory tests included triaxial compression, double direct shear, consolidation, Atterberg limit tests and determinations of moisture contents and dry densities. The method of performing various tests are described on Exhibits A-2 through A-4 of this Appendix, and information concerning the specific tests conducted is presented below.

Strength Tests - Triaxial compression and double direct shear tests were performed to determine the strength characteristics of the soil penetrated by the borings. Triaxial compression tests were performed under unconsolidated-undrained conditions at both natural moisture content and saturation. The double direct shear tests were

performed at a strain rate of .02 inches per minute. Tri-axial compression tests were performed under both stress control and strain control as noted in the tables below. The results of the various strength tests are as follows:

DOUBLE DIRECT SHEAR TESTS

Boring No.	Depth (Ft.)	Normal Pressure (lbs/sq ft)	Peak Shear Stress (lbs/sq ft)
9	31.5	3000	2900
9	41.0	4000	3700
19	6.0	4000	5800
19	6.0	5000	5190

UNCONSOLIDATED-UNDRAINED TRIAXIAL TESTS  
(Stress Controlled)  
Natural Moisture

Boring No.	Depth (Ft.)	Confining Pressure (lbs/sq ft)	Peak Deviator Stress* (lbs/sq ft)	Loading Rate (lbs/sq ft/min)
13	6	2000	20,000+	400
13	11	1000	20,000+	200
13	21	4000	20,000+	200
21	11	200	4,520	200

\*Peak deviator stress exceeded limit of testing apparatus with maximum strains of 2.2%.



UNCONSOLIDATED-UNDRAINED TRIAXIAL TESTS\*  
(Strain Controlled)  
Saturated

Boring No.	Depth (Ft.)	Confining and Saturation Pressure (lbs/sq ft)	Deviator Stress @ 10% Strain (lbs/sq ft)	Strain Rate (in/min)
2	40.5	8000	5378	0.05
2	45.5	6000	5783	0.05
8	20.5	2000	7889	0.05
11	31.0	4000	12652	0.05

Consolidation Tests - Two consolidation tests were performed, and the results are presented on Plate A-3.

Atterberg Limits - Four Atterberg limits determinations were conducted to classify and correlate selected samples. Results of these tests are as follows:

Boring No.	Depth (Ft.)	Liquid Limit (%)	Plastic Limit (%)
2	50.5	118	64
9	41.0	103	60
12	4.5	70	45
13	6.0	61	49
15	4.0	75	56

All of the above tests fall within the MH classification of the Unified Soil Classification System.

\*An average shear strength of 2900 psf was selected from these test results for analyzing the slope stability.

Moisture and Density Tests - Moisture and density tests were performed in conjunction with each strength and consolidation test. Additional moisture and density tests were performed for correlation purposes. The results of the moisture and density determinations are presented on the Log of Borings.

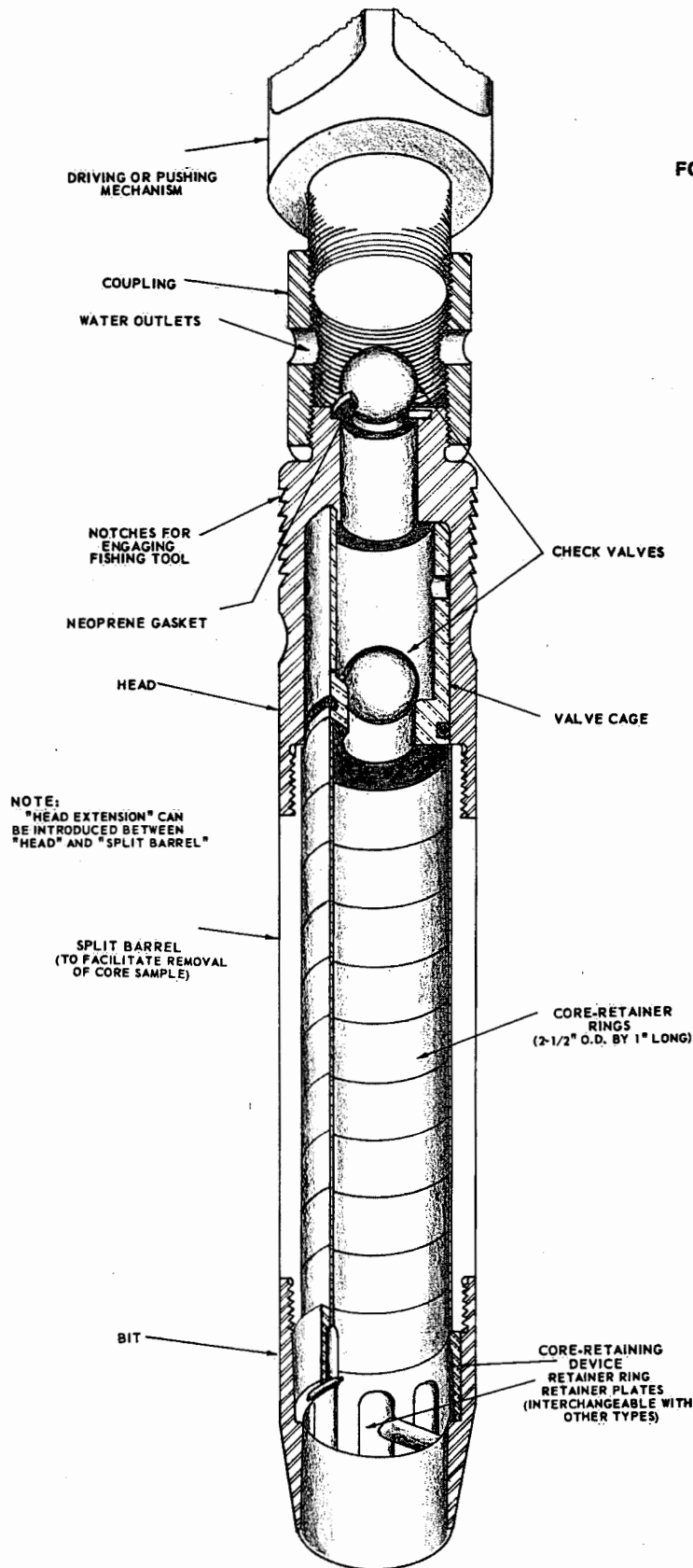
Compaction Test - A compaction curve for the on-site surface soil is presented on Plate A-4.



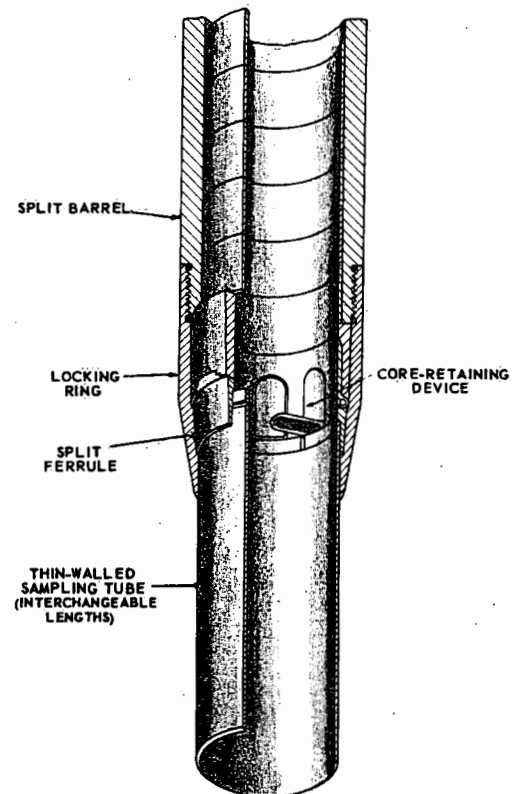
The following Exhibits and Plates are attached and complete this Appendix:

- Exhibit A-1 - Soil Sampler, Type U
- Exhibit A-2 - Method of Performing Unconfined Compression and Triaxial Compression Tests
- Exhibit A-3 - Method of Performing Direct Shear and Friction Tests
- Exhibit A-4 - Method of Performing Consolidation Tests
- Plate A-1A - Log of Borings, Borings 1, 2 and 3
- Plate A-1B - Log of Borings, Borings 4, 5, 6 and 7
- Plate A-1C - Log of Borings, Borings 8, 9, 10 and 11
- Plate A-1D - Log of Borings, Borings 12, 13, 14 and 14A
- Plate A-1E - Log of Borings, Borings 15, 16, 17, 18, 19 and 20
- Plate A-1F - Log of Borings, Borings 21 and 22
- Plate A-2 - Unified Soil Classification System
- Plate A-3 - Consolidation Test Data
- Plate A-4 - Compaction Test Data

**SOIL SAMPLER TYPE U**  
FOR SOILS DIFFICULT TO RETAIN IN SAMPLER



**ALTERNATE ATTACHMENTS**

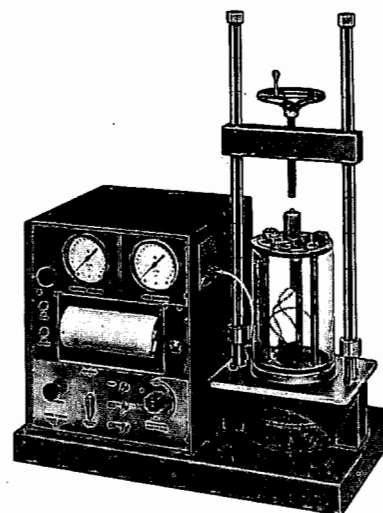


## EXHIBIT A-2

### METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.



TRIAXIAL COMPRESSION TEST UNIT

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

UNCONSOLIDATED-UNDRAINED: THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

CONSOLIDATED-UNDRAINED: THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

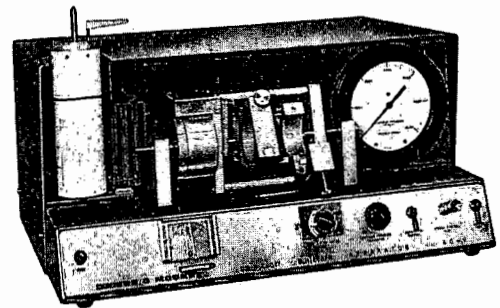
DRAINED: THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

## EXHIBIT A-3

### METHOD OF PERFORMING DIRECT SHEAR AND FRICTION TESTS

DIRECT SHEAR TESTS ARE PERFORMED TO DETERMINE THE SHEARING STRENGTHS OF SOILS. FRICTION TESTS ARE PERFORMED TO DETERMINE THE FRICTIONAL RESISTANCES BETWEEN SOILS AND VARIOUS OTHER MATERIALS SUCH AS WOOD, STEEL, OR CONCRETE. THE TESTS ARE PERFORMED IN THE LABORATORY TO SIMULATE ANTICIPATED FIELD CONDITIONS.



**DIRECT SHEAR TESTING  
& RECORDING APPARATUS**

EACH SAMPLE IS TESTED WITHIN THREE BRASS RINGS, TWO AND ONE-HALF INCHES IN DIAMETER AND ONE INCH IN LENGTH. UNDISTURBED SAMPLES OF IN-PLACE SOILS ARE TESTED IN RINGS TAKEN FROM THE SAMPLING DEVICE IN WHICH THE SAMPLES WERE OBTAINED. LOOSE SAMPLES OF SOILS TO BE USED IN CONSTRUCTING EARTH FILLS ARE COMPACTED IN RINGS TO PREDETERMINED CONDITIONS AND TESTED.

#### DIRECT SHEAR TESTS

A THREE-INCH LENGTH OF THE SAMPLE IS TESTED IN DIRECT DOUBLE SHEAR. A CONSTANT PRESSURE, APPROPRIATE TO THE CONDITIONS OF THE PROBLEM FOR WHICH THE TEST IS BEING PERFORMED, IS APPLIED NORMAL TO THE ENDS OF THE SAMPLE THROUGH POROUS STONES. A SHEARING FAILURE OF THE SAMPLE IS CAUSED BY MOVING THE CENTER RING IN A DIRECTION PERPENDICULAR TO THE AXIS OF THE SAMPLE. TRANSVERSE MOVEMENT OF THE OUTER RINGS IS PREVENTED.

THE SHEARING FAILURE MAY BE ACCOMPLISHED BY APPLYING TO THE CENTER RING EITHER A CONSTANT RATE OF LOAD, A CONSTANT RATE OF DEFLECTION, OR INCREMENTS OF LOAD OR DEFLECTION. IN EACH CASE, THE SHEARING LOAD AND THE DEFLECTIONS IN BOTH THE AXIAL AND TRANSVERSE DIRECTIONS ARE RECORDED AND PLOTTED. THE SHEARING STRENGTH OF THE SOIL IS DETERMINED FROM THE RESULTING LOAD-DEFLECTION CURVES.

#### FRICTION TESTS

IN ORDER TO DETERMINE THE FRICTIONAL RESISTANCE BETWEEN SOIL AND THE SURFACES OF VARIOUS MATERIALS, THE CENTER RING OF SOIL IN THE DIRECT SHEAR TEST IS REPLACED BY A DISK OF THE MATERIAL TO BE TESTED. THE TEST IS THEN PERFORMED IN THE SAME MANNER AS THE DIRECT SHEAR TEST BY FORCING THE DISK OF MATERIAL FROM THE SOIL SURFACES.

## EXHIBIT A-4

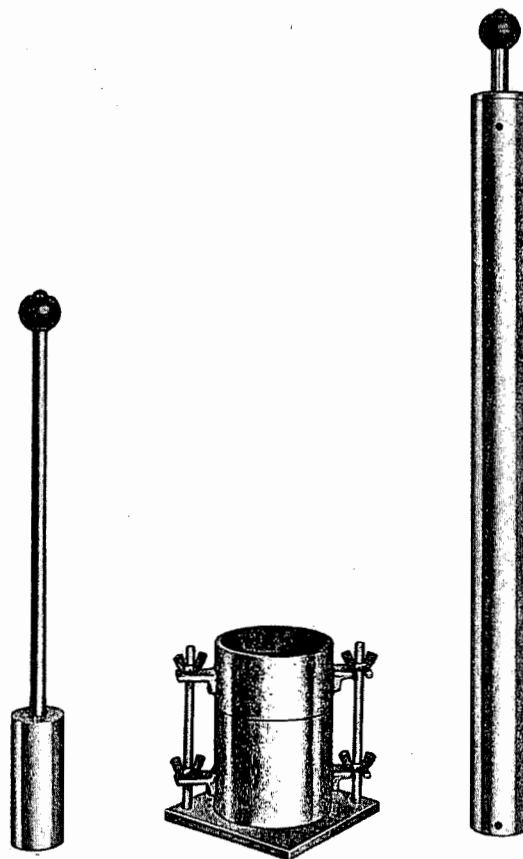
### METHOD OF PERFORMING COMPACTION TESTS (STANDARD AND MODIFIED A.A.S.H.O. METHODS)

IT HAS BEEN ESTABLISHED THAT WHEN COMPACTING EFFORT IS HELD CONSTANT, THE DENSITY OF A ROLLED EARTH FILL INCREASES WITH ADDED MOISTURE UNTIL A MAXIMUM DRY DENSITY IS OBTAINED AT A MOISTURE CONTENT TERMED THE "OPTIMUM MOISTURE CONTENT," AFTER WHICH THE DRY DENSITY DECREASES. THE COMPACTION CURVE SHOWING THE RELATIONSHIP BETWEEN DENSITY AND MOISTURE CONTENT FOR A SPECIFIC COMPACTING EFFORT IS DETERMINED BY EXPERIMENTAL METHODS. TWO COMMONLY USED METHODS ARE DESCRIBED IN THE FOLLOWING PARAGRAPHS.

FOR THE "STANDARD A.A.S.H.O." (A.S.T.M. D698-58T & A.A.S.H.O. T99-57) METHOD OF COMPACTION A PORTION OF THE SOIL SAMPLE PASSING THE NO. 4 SIEVE IS COMPACTED AT A SPECIFIC MOISTURE CONTENT IN THREE EQUAL LAYERS IN A STANDARD COMPACTION CYLINDER HAVING A VOLUME OF  $1/30$  CUBIC FOOT, USING TWENTY-FIVE 12-INCH BLOWS OF A STANDARD 5-1/2 POUND RAMMER TO COMPACT EACH LAYER.


IN THE "MODIFIED A.A.S.H.O." (A.S.T.M. D-1557-58T & A.A.S.H.O. T 180-57) METHOD OF COMPACTION A PORTION OF THE SOIL SAMPLE PASSING THE NO. 4 SIEVE IS COMPACTED AT A SPECIFIC MOISTURE CONTENT IN FIVE EQUAL LAYERS IN A STANDARD COMPACTION CYLINDER HAVING A VOLUME OF  $1/30$  CUBIC FOOT, USING TWENTY-FIVE 18-INCH BLOWS OF A 10-POUND RAMMER TO COMPACT EACH LAYER. SEVERAL VARIATIONS OF THESE COMPACTION TESTING METHODS ARE OFTEN USED AND THESE ARE DESCRIBED IN A.A.S.H.O. & A.S.T.M. SPECIFICATIONS.

FOR BOTH METHODS, THE WET DENSITY OF THE COMPACTED SAMPLE IS DETERMINED BY WEIGHING THE KNOWN VOLUME OF SOIL; THE MOISTURE CONTENT, BY MEASURING THE LOSS OF WEIGHT OF A PORTION OF THE SAMPLE WHEN OVEN DRIED; AND THE DRY DENSITY, BY COMPUTING IT FROM THE WET DENSITY AND MOISTURE CONTENT. A SERIES OF SUCH COMPACTIONS IS PERFORMED AT INCREASING MOISTURE CONTENTS UNTIL A SUFFICIENT NUMBER OF POINTS DEFINING THE MOISTURE-DENSITY RELATIONSHIP HAVE BEEN OBTAINED TO PERMIT THE PLOTTING OF THE COMPACTION CURVE. THE MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT FOR THE PARTICULAR COMPACTING EFFORT ARE DETERMINED FROM THE COMPACTION CURVE.



SOME APPARATUS FOR PERFORMING COMPACTION TESTS  
Shows, from left to right, 5-1/2 pound rammer (sleeve controlling 12" height of drop removed), 1/30 cubic-foot cylinder with removable collar and base plate, and 10 pound rammer within sleeve.





BORING 1					
SURFACE ELEVATION 695'					
MOISTURE CONTENT IN %	DRY DENSITY IN PCF	BLOWS/FT. ON SAMPLER	TYPE OF SAMPLE AND/OR CORE AND % RECOVERY SAMPLES AND/OR CORES	DEPTH IN FEET	LETTER SYMBOL
26.9	95	80		10-	MH
		57			
		76			
		81			
DESCRIPTION					
RED-BROWN CLAYEY SILT (HARD) THIN ROOT SYSTEM TO 1' GRADING WITH OCCASIONAL PEA GRAVEL					
BORING COMPLETED AT 15.0 FEET ON 2-2-70 NO GROUNDWATER ENCOUNTERED					




BORING COMPLETED AT 15.0 FEET ON 2-2-70  
NO GROUNDWATER ENCOUNTERED

### BORING 3

SURFACE ELEVATION 697'

29.8	94	30+			MH	RED-BROWN CLAYEY SILT (FILL) (FIRM)	
		90/9'			MH	RED-BROWN CLAYEY SILT WITH OCCASIONAL PEA GRAVEL (HARD)	
		72				STIFF WITH THIN ROOT SYSTEM TO 3'	
DESCRIPTION							

BORING COMPLETED AT 15.3 FEET ON 2-2-70  
NO GROUNDWATER ENCOUNTERED

BORING 2					
SURFACE ELEVATION 697'					
MOISTURE CONTENT IN %	DRY DENSITY IN PCF	BLOWS/FT. ON SAMPLER	TYPE OF SAMPLE AND/OR CORE AND % RECOVERY SAMPLES AND/OR CORES	DEPTH IN FEET	LETTER SYMBOL
DESCRIPTION					
29.8	91	46		10-	MH
		49			
43.5	80	19		20-	
		50			
24.6	100	40		30-	
35.4	90	17			
43.5	78	12		40-	
43.9	76	14			
43.6	78	18		50-	
45.2	73	14			
RED-BROWN CLAYEY SILT (STIFF TO VERY STIFF)					
FIRM 12' TO 18'					
MOIST FIRM AND LESS DENSE BELOW 28'					
HOLE CAVED AFTER LAST SAMPLE					

HOLE CAVED AFTER LAST SAMPLE  
BORING COMPLETED AT 51.5 FEET ON 2-2-70  
NO GROUNDWATER ENCOUNTERED

#### NOTES:

- - DEPTH AT WHICH UNDISTURBED SAMPLE WAS TAKEN
  - ⊗ - DEPTH AT WHICH DISTURBED SAMPLE WAS TAKEN
  - - DEPTH AT WHICH SAMPLE WAS LOST DURING EXTRACTION
  - I - DEPTH AND LENGTH OF CORE RUN
- DRIVING ENERGY - 300 -LB WEIGHT DROPPING 30 INCHES

## LOG OF BORINGS

MOISTURE CONTENT IN %	DRY DENSITY IN PCF	BLOWS/FT. ON SAMPLER	TYPE OF SAMPLE AND/OR CORE AND % RECOVERY	DEPTH IN FEET	GRAPH SYMBOL	LETTER SYMBOL

### DESCRIPTION

BORING COMPLETED AT 10.0 FEET ON 2-2-70  
 NO GROUNDWATER ENCOUNTERED

SURFACE ELEVATION 697'

BORING COMPLETED AT 20.5 FEET ON 2-2-70  
NO GROUNDWATER ENCOUNTERED

MOISTURE CONTENT IN %	TYPE OF SAMPLE AND/OR CORE AND % RECOVERY
DRY DENSITY IN PCF	SAMPLES AND/OR CORES
BLOWS/FT. ON SAMPLER	DEPTH IN FEET
	GRAPH SYMBOL
	FILTER SYMBOL

### DESCRIPTION

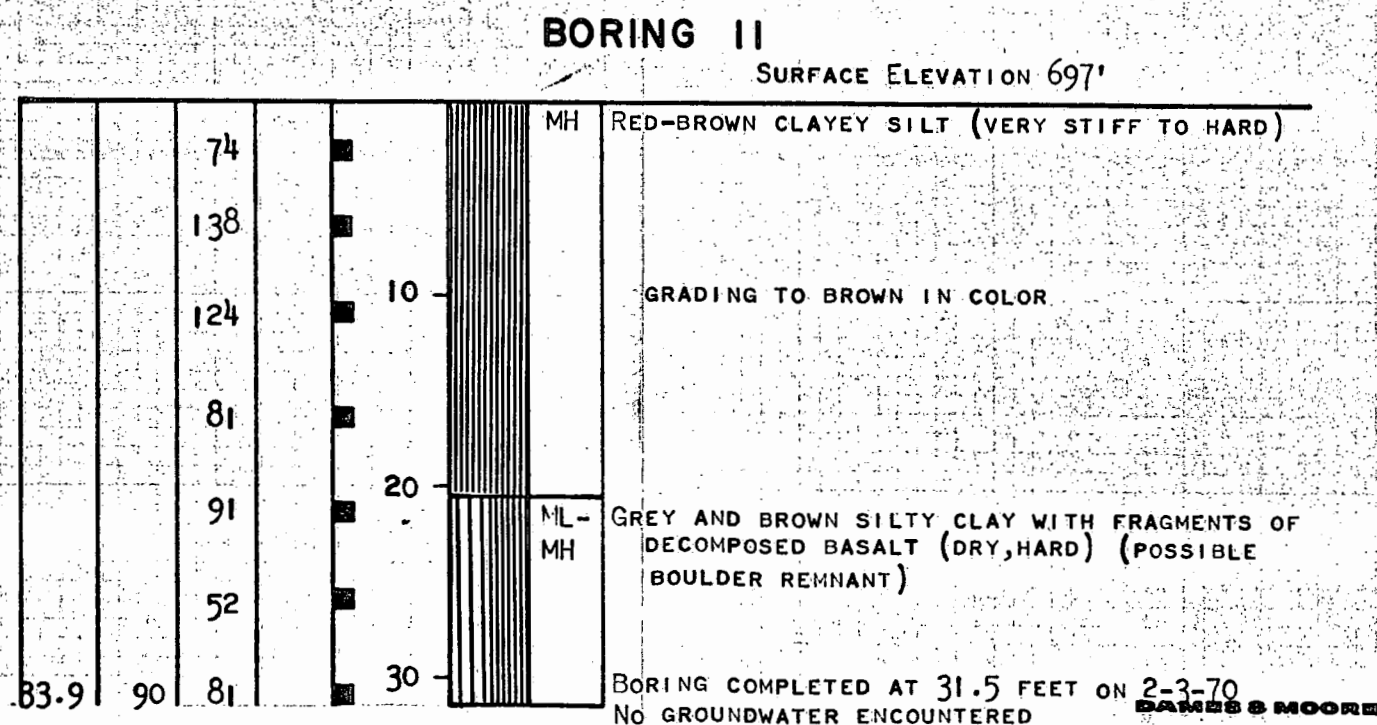
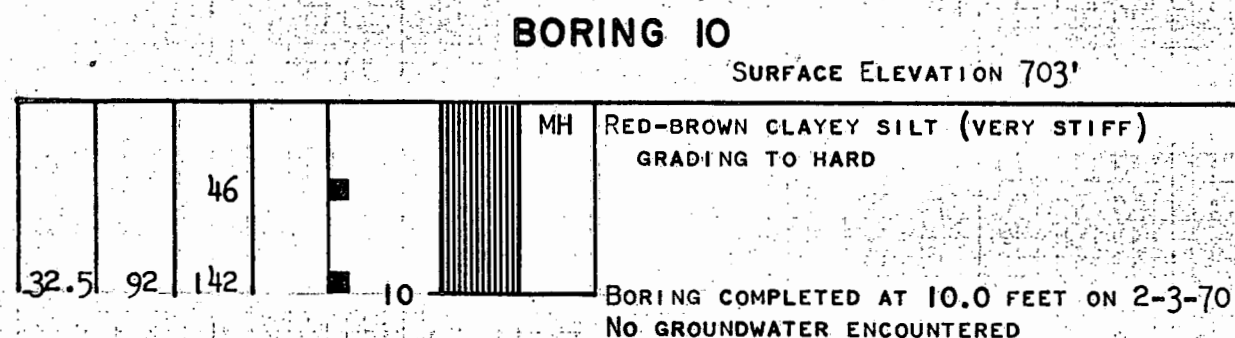
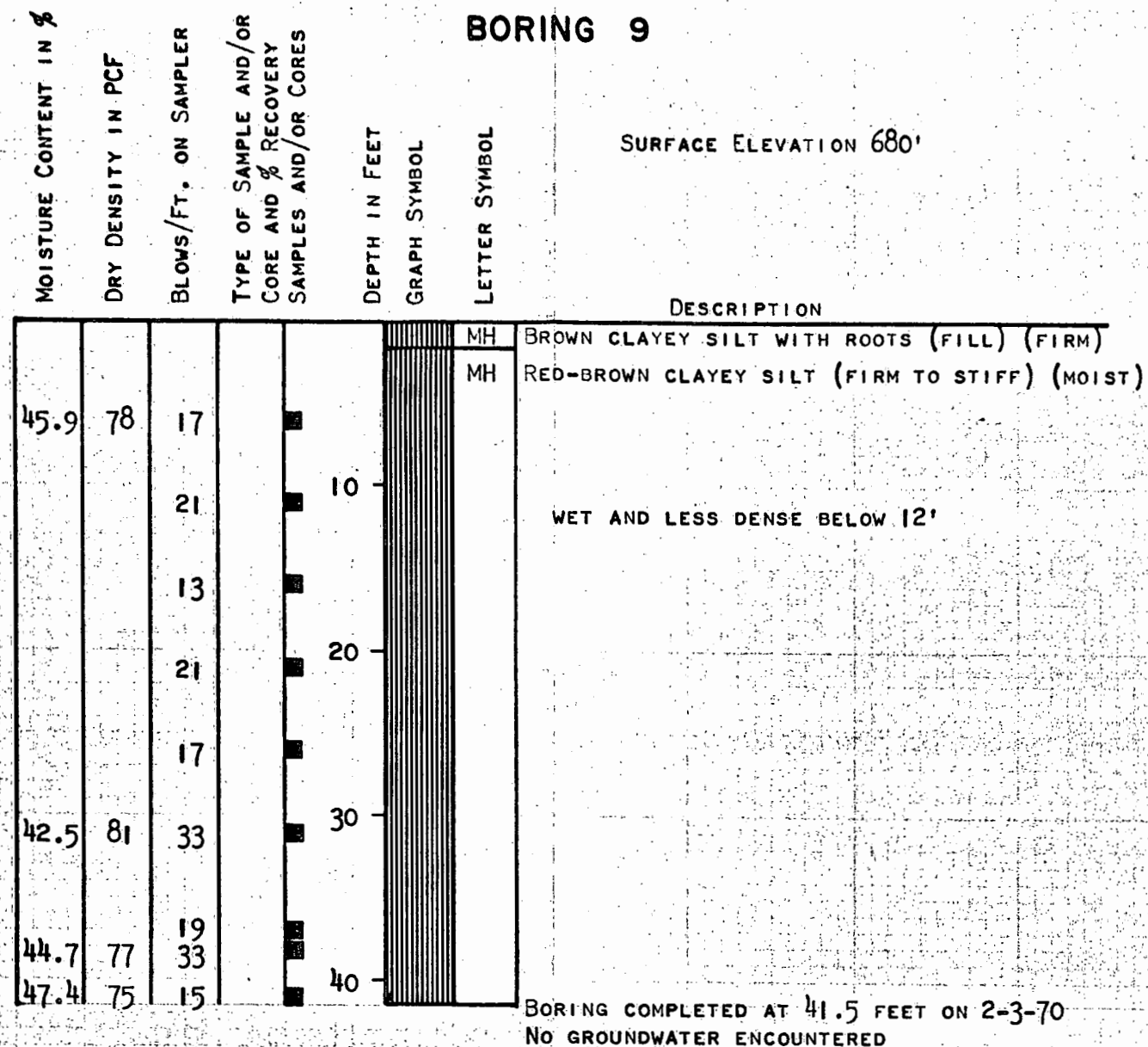
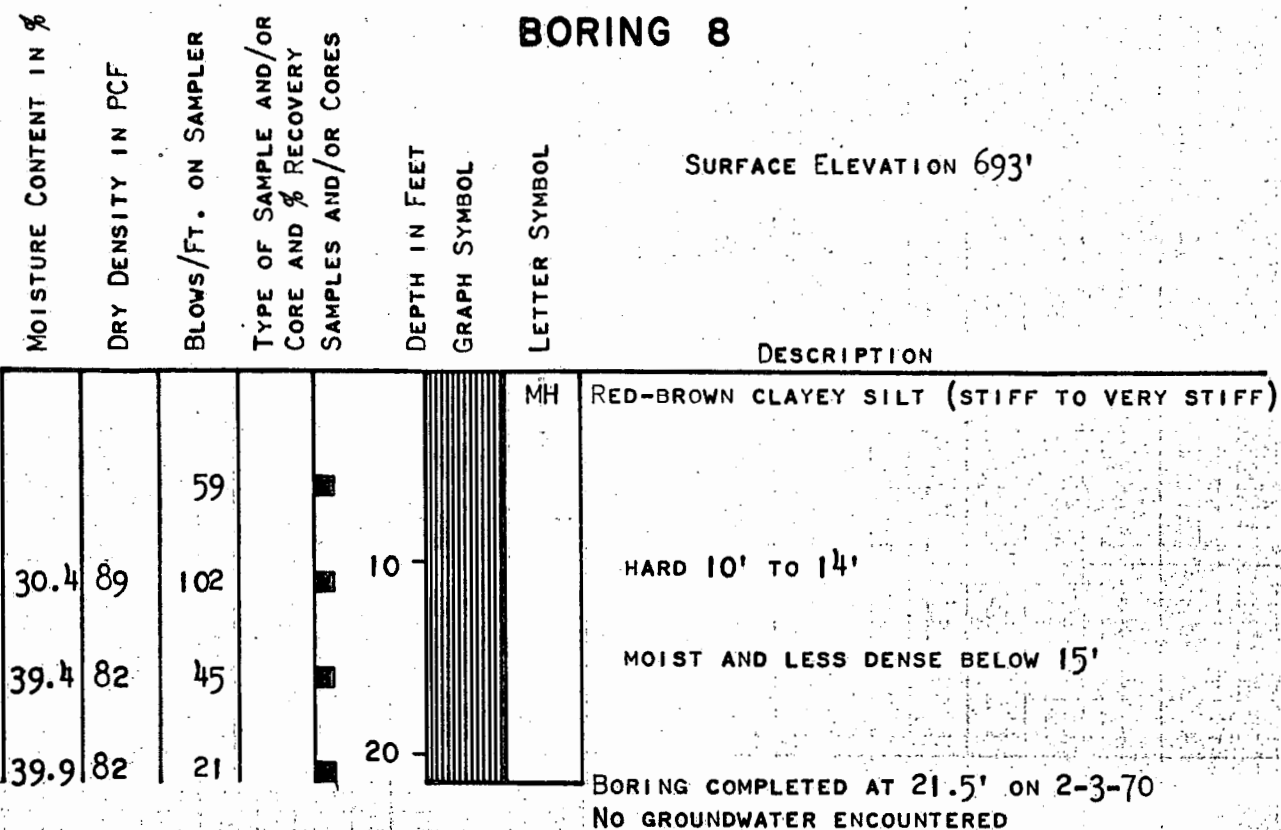
BORING COMPLETED AT 15.0 FEET ON 2-2-70  
NO GROUNDWATER ENCOUNTERED

**SURFACE ELEVATION 696'**

BORING COMPLETED AT 11.5 FEET ON 2-3-70  
NO GROUNDWATER ENCOUNTERED

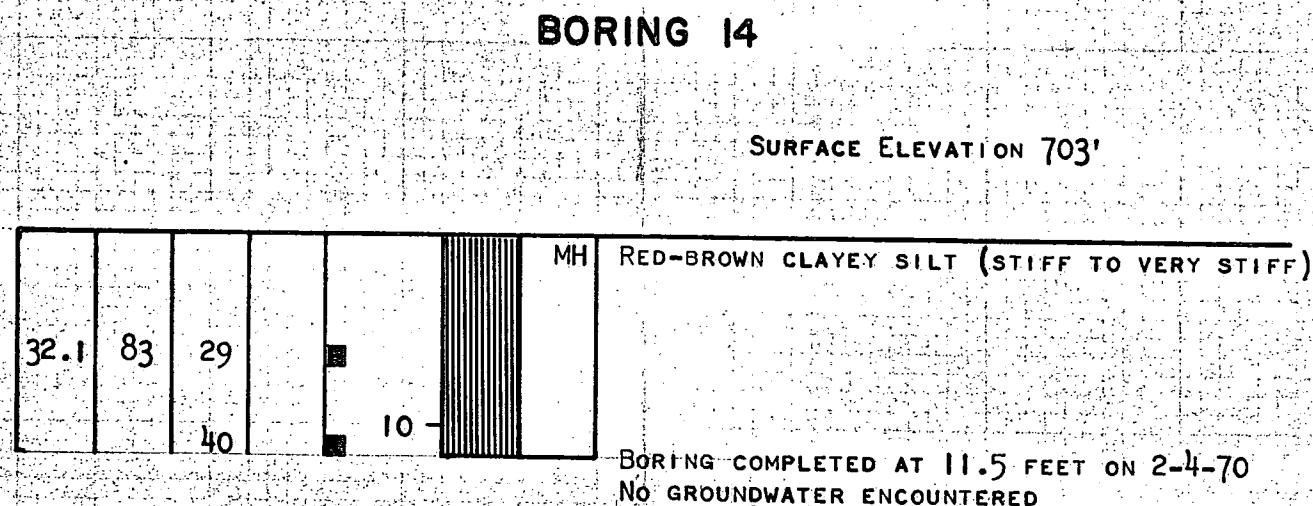
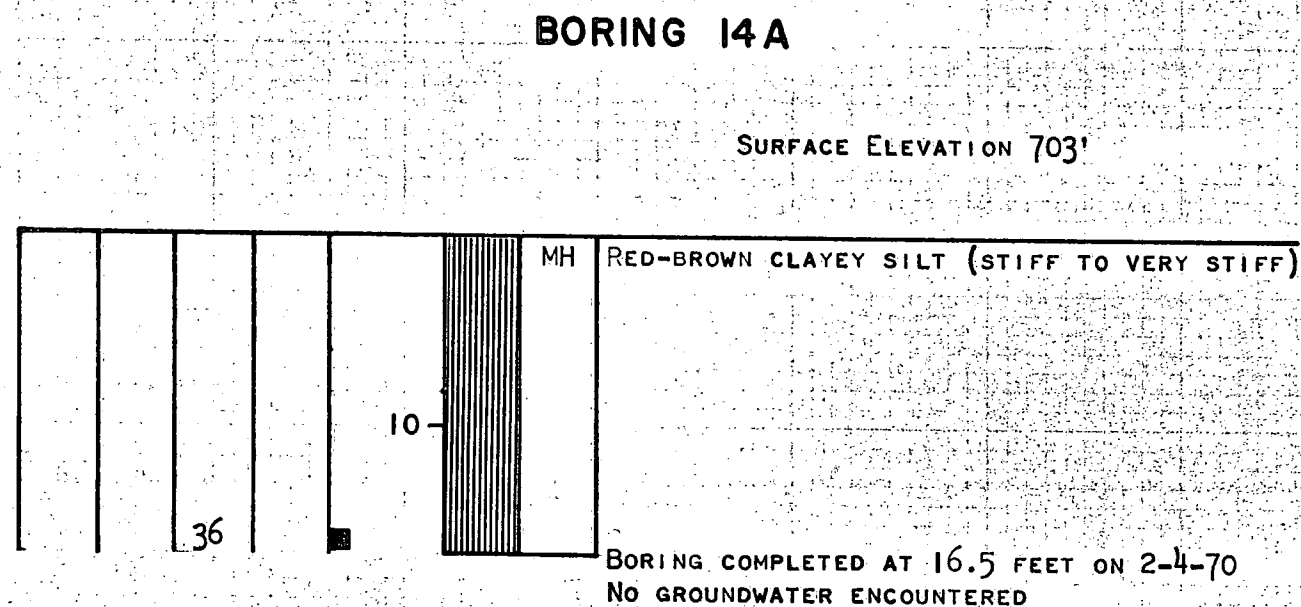
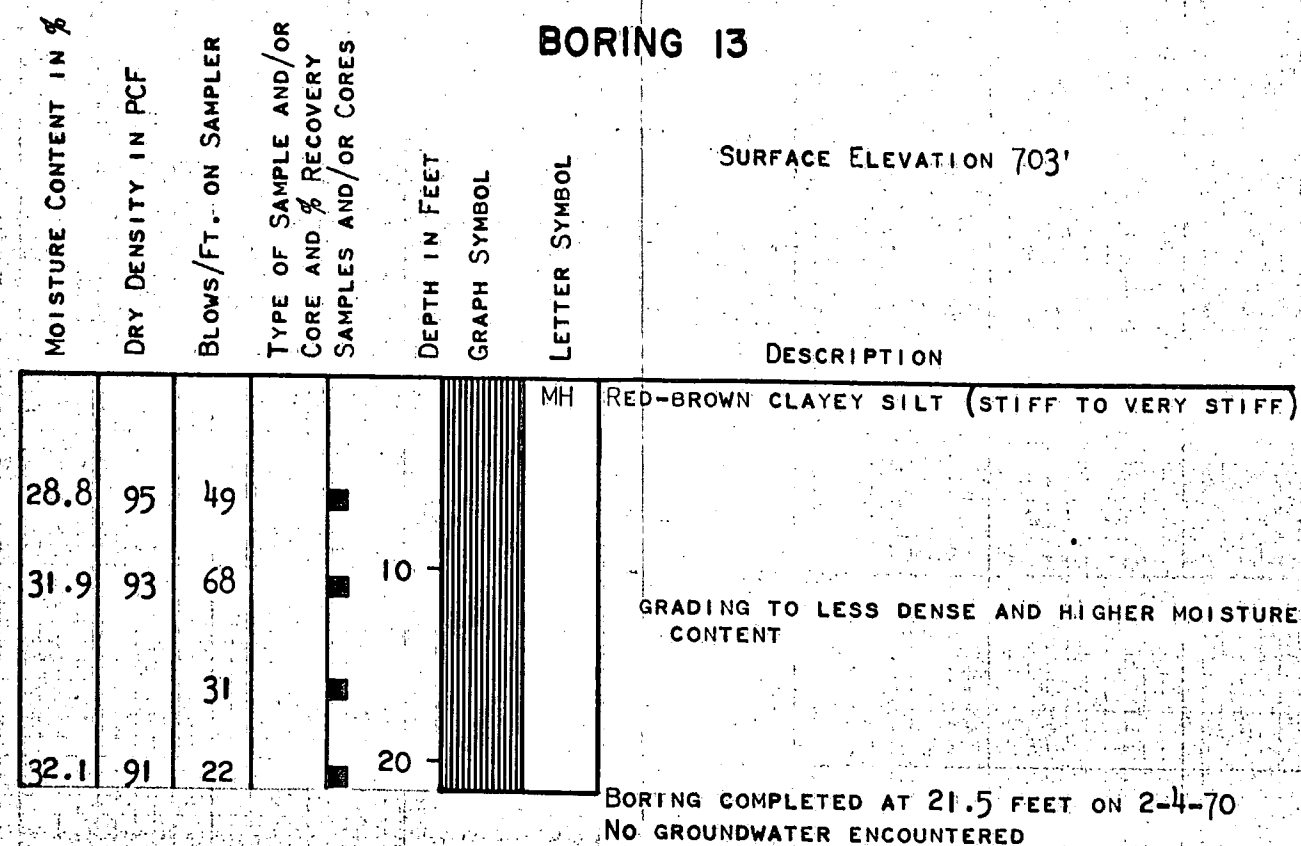
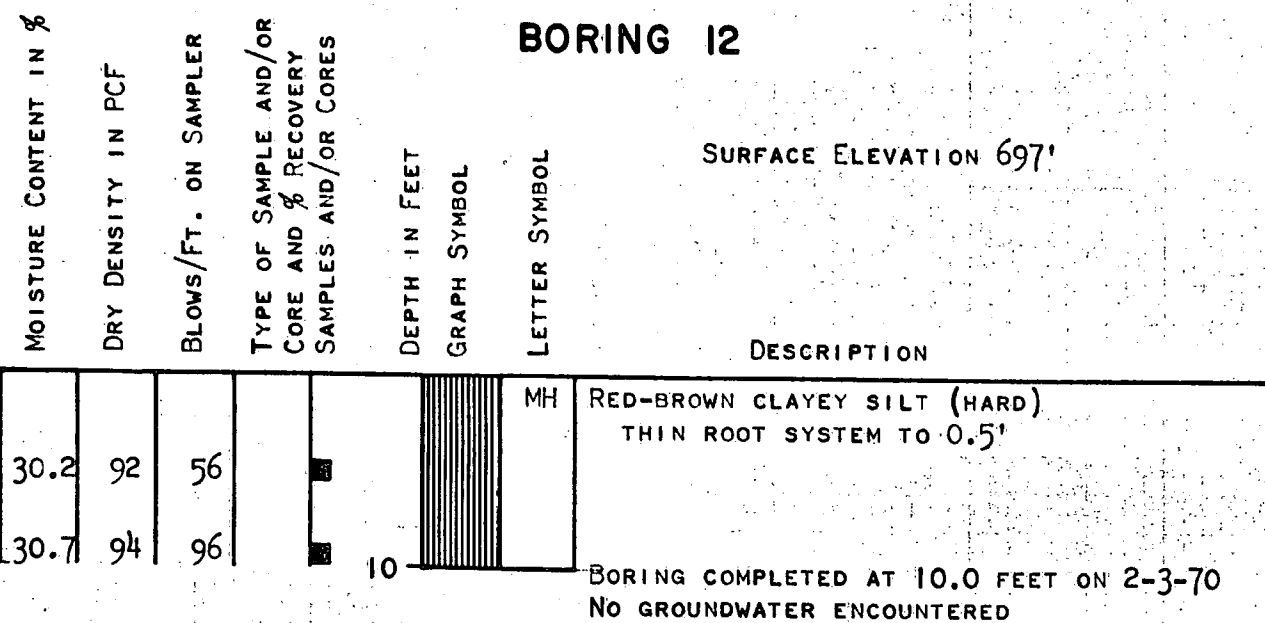
**DAMES & MOORE**



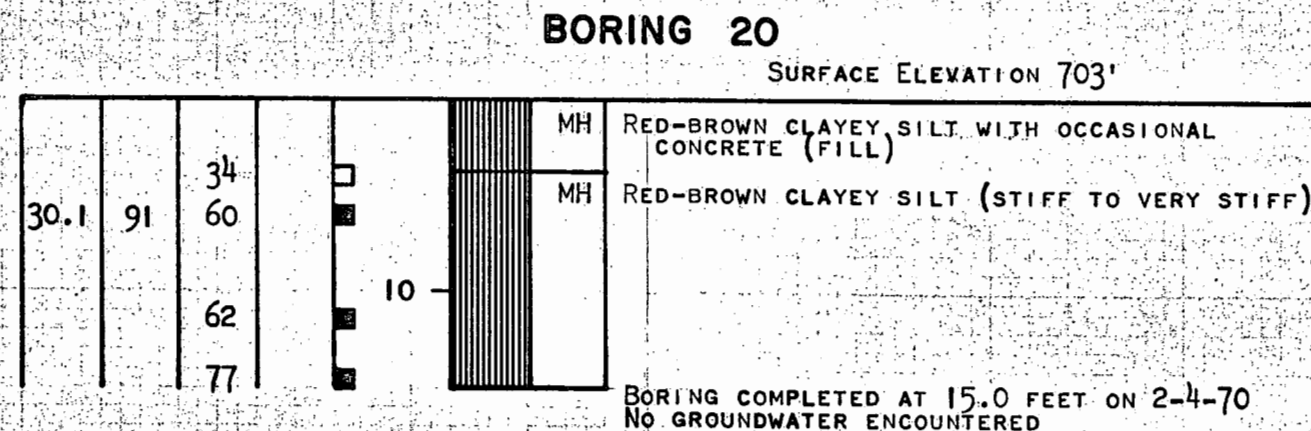
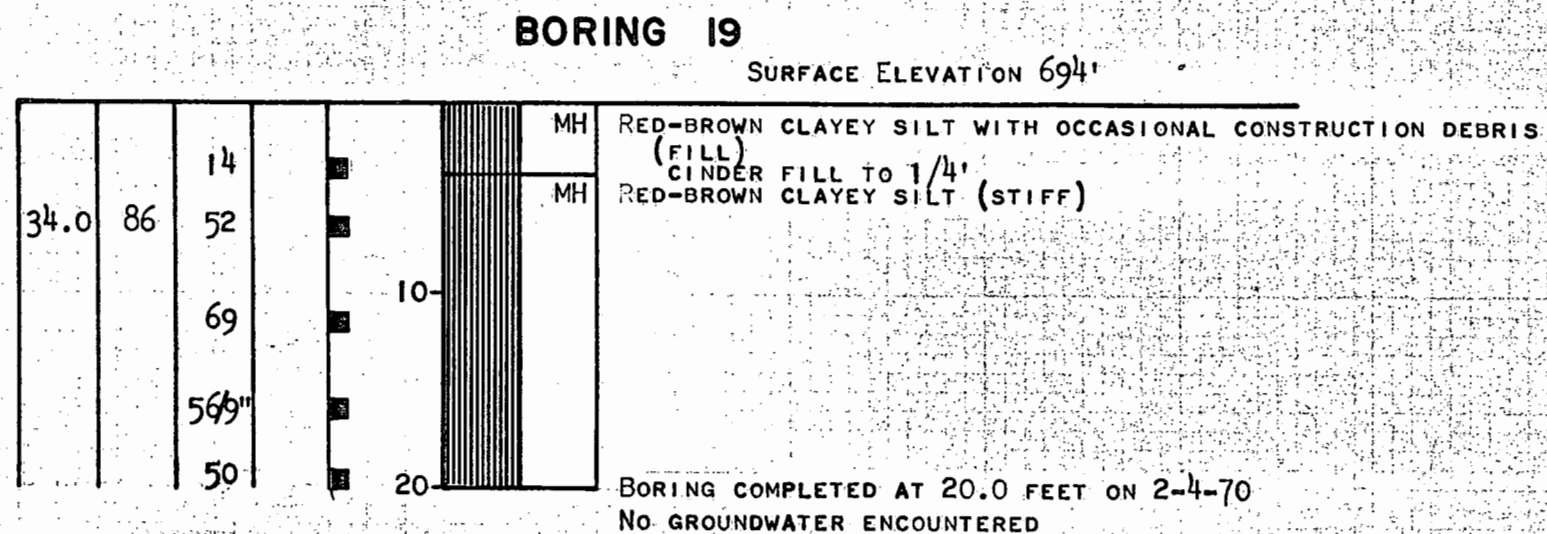
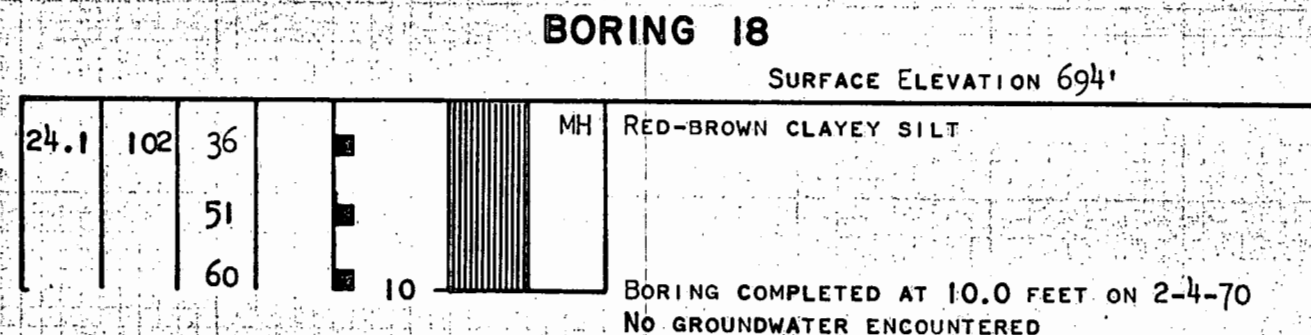
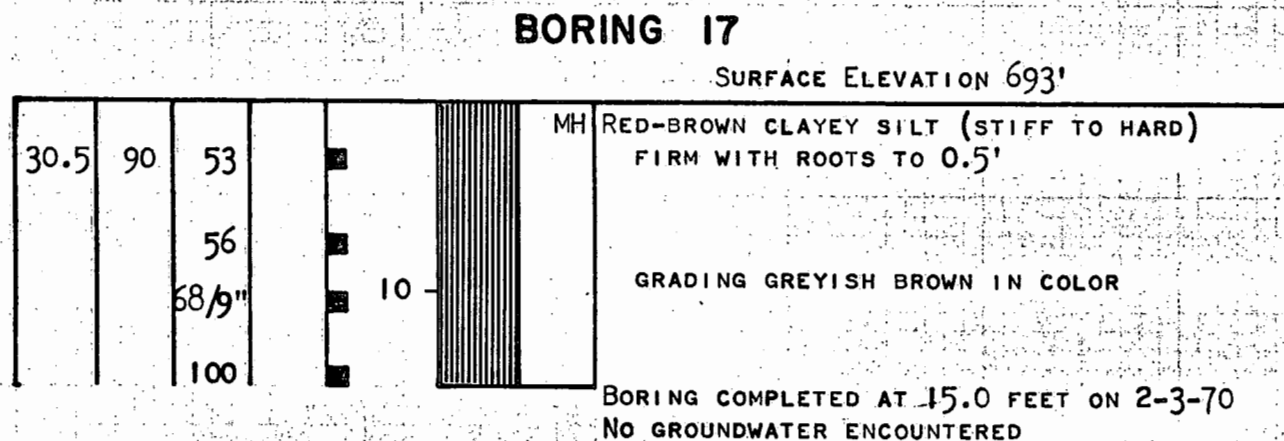
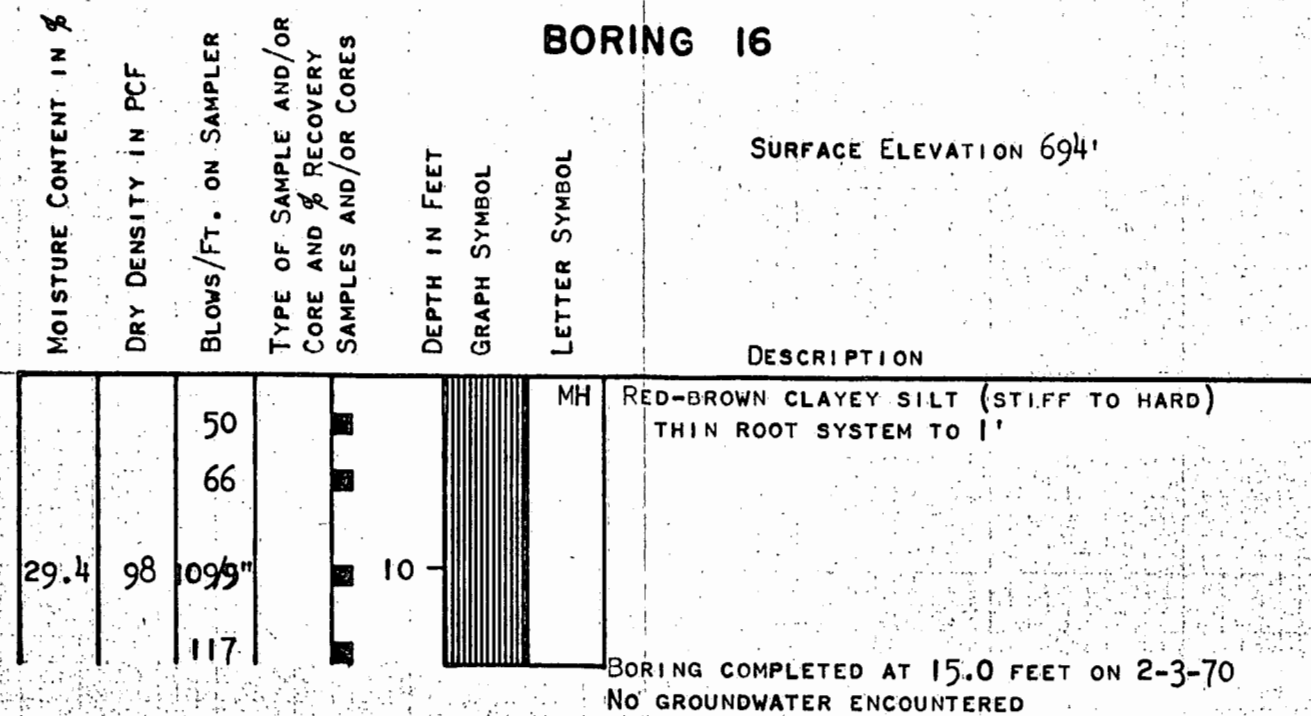
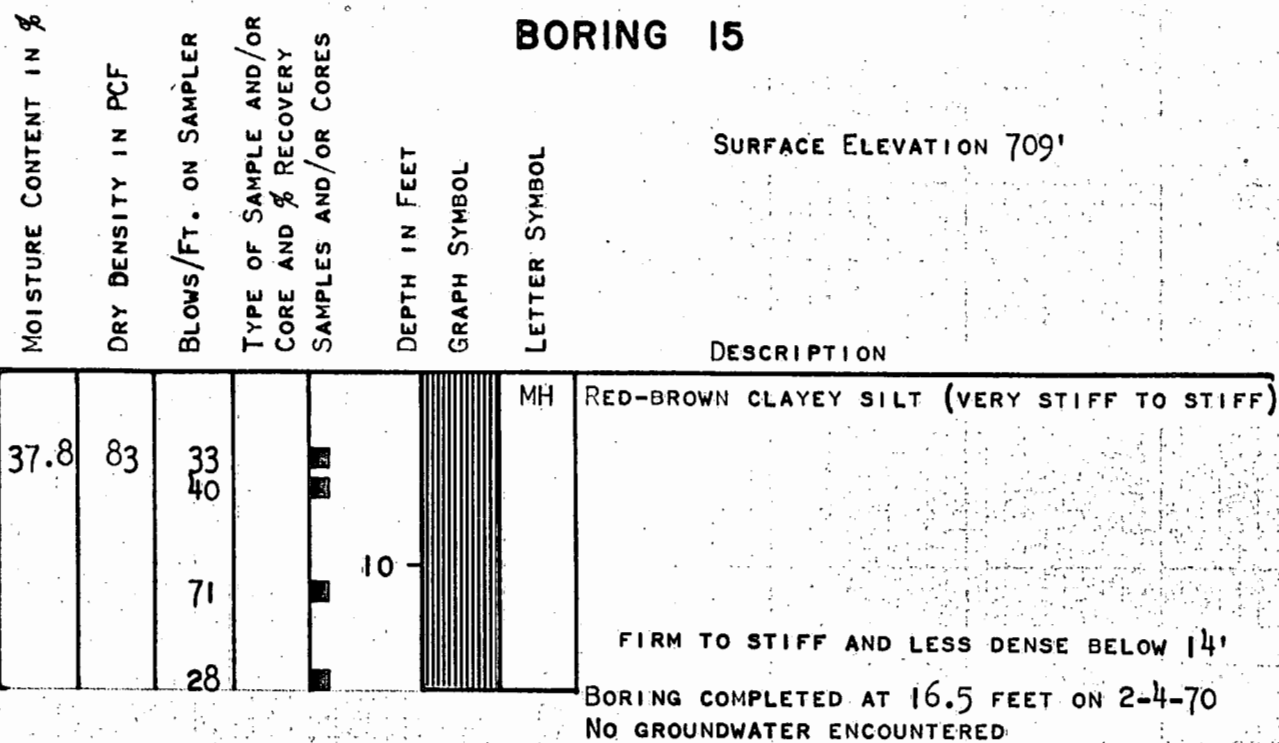


LOG OF BORINGS





LOG OF BORINGS



LOG OF BORINGS

946.7 (REV. 6-61)

REVISIONS

BY \_\_\_\_\_ DATE \_\_\_\_\_

FILE 7503-002

DATE \_\_\_\_\_

CHECKED BY \_\_\_\_\_

# BORING 21

SURFACE ELEVATION 749'

MOISTURE CONTENT IN %	DRY DENSITY IN PCF	BLOWS/FT. ON SAMPLER	TYPE OF SAMPLE AND/OR CORE AND % RECOVERY	SAMPLES AND/OR CORES	DEPTH IN FEET	GRAPH SYMBOL	LETTER SYMBOL	DESCRIPTION
37.8	79	8		■	10		MH	RED-BROWN CLAYEY SILT (FIRM)
37.0	78	18		■				GRADES TO VERY CLAYEY BELOW 3'
		55		■				GRADES TO LESS CLAYEY BELOW 14'
BORING COMPLETED AT 16.5 FEET ON 2-4-70 NO GROUNDWATER ENCOUNTERED								

# BORING 22

SURFACE ELEVATION 738'

36.3	85	24					MH	RED-BROWN CLAYEY SILT (FIRM)
		14						
		25			10			
BORING COMPLETED AT 12.0 FEET ON 2-4-70 NO GROUNDWATER ENCOUNTERED								

## LOG OF BORINGS

### NOTES:

- - DEPTH AT WHICH UNDISTURBED SAMPLE WAS TAKEN
  - ⊠ - DEPTH AT WHICH DISTURBED SAMPLE WAS TAKEN
  - - DEPTH AT WHICH SAMPLE WAS LOST DURING EXTRACTION
  - I - DEPTH AND LENGTH OF CORE RUN
- DRIVING ENERGY - 300-LB WEIGHT DROPPING 30 INCHES

DAMES & MOORE

SOIL CLASSIFICATION CHART

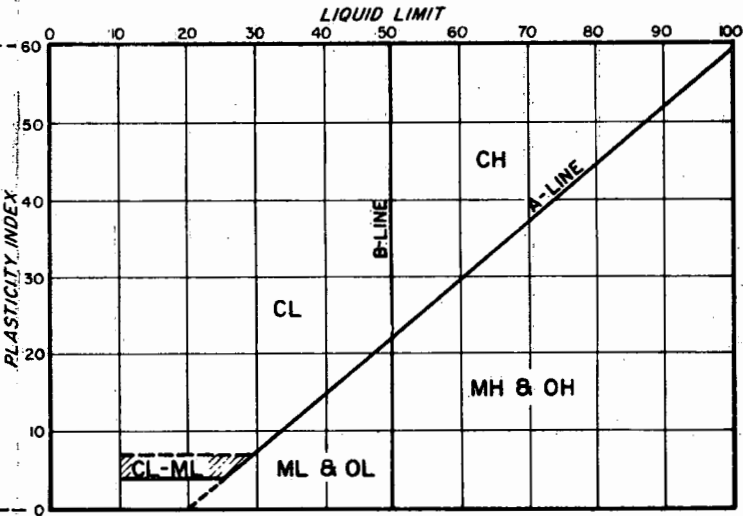
MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS	
COARSE GRAINED SOILS  MORE THAN 50 % OF MATERIAL IS <u>LARGER</u> THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS  MORE THAN 50 % OF COARSE FRACTION <u>RETAINED</u> ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	
				GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	
	SAND AND SANDY SOILS  MORE THAN 50% OF COARSE FRACTION <u>PASSING</u> NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	
				SM	SILTY SANDS, SAND-SILT MIXTURES	
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES	
FINE GRAINED SOILS  MORE THAN 50 % OF MATERIAL IS <u>SMALLER</u> THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS  LIQUID LIMIT LESS THAN 50			ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY	
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS	
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	
				MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS	
	SILTS AND CLAYS  LIQUID LIMIT <u>GREATER</u> THAN 50			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS	
		HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

GRADATION CHART

MATERIAL SIZE	PARTICLE SIZE			
	LOWER LIMIT		UPPER LIMIT	
	MILLIMETERS	SIEVE SIZE*	MILLIMETERS	SIEVE SIZE*
SAND				
	FINE	.075	#200*	0.425
	MEDIUM	0.425	#40*	0.850
GRAVEL				
	FINE	0.850	#20*	2.000
	COARSE	2.000	#10*	4.750
COBBLES				
	FINE	4.750	#4*	19.0
	COARSE	19.0	3/4"*	76.2
BOULDERS	76.2	3"*	304.8	12"*
	304.8	12"*	914.4	36"*

\* U.S. STANDARD      \* CLEAR SQUARE OPENINGS

PLASTICITY CHART



- NOTES:
- DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE CLASSIFICATIONS.
  - WHEN SHOWN ON THE BORING LOGS, THE FOLLOWING TERMS ARE USED TO DESCRIBE THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE COMPACTNESS OF COHESIONLESS SOILS.

COHESIVE SOILS		COHESIONLESS SOILS	
	(APPROXIMATE SHEARING STRENGTH IN KSF)		
VERY SOFT	LESS THAN .25	VERY LOOSE	THESE ARE USUALLY BASED ON AN EXAMINATION OF SOIL SAMPLES, PENETRATION RESISTANCE, AND SOIL DENSITY DATA.
SOFT	0.25 TO 0.5	LOOSE	
MEDIUM STIFF	0.5 TO 1.0	MEDIUM DENSE	
STIFF	1.0 TO 2.0	DENSE	
VERY STIFF	2.0 TO 4.0	VERY DENSE	
HARD	GREATER THAN 4.0		

SAMPLES

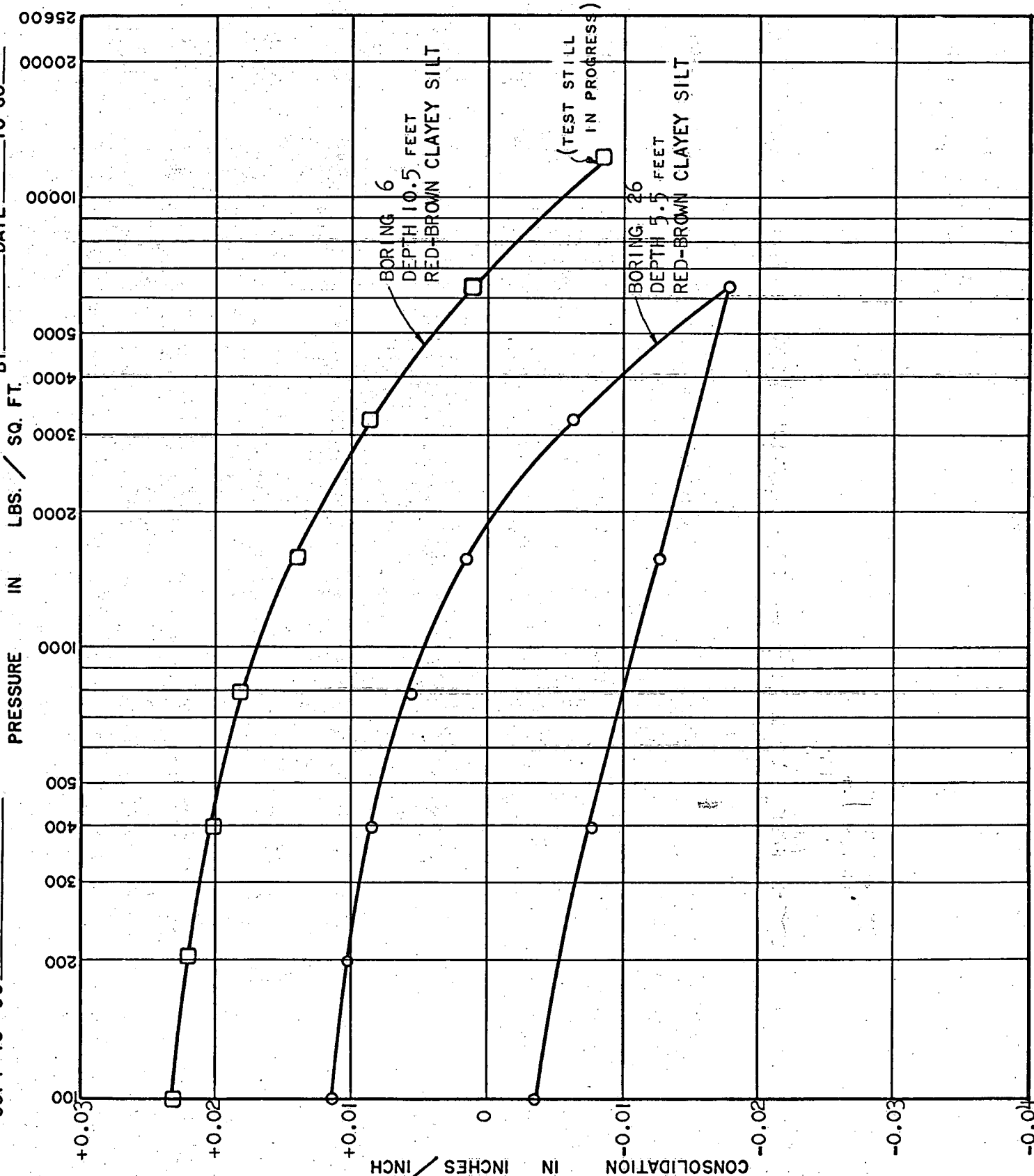
- INDICATES UNDISTURBED SAMPLE
- INDICATES DISTURBED SAMPLE
- INDICATES SAMPLING ATTEMPT WITH NO RECOVERY
- INDICATES LENGTH OF CORING RUN

NOTE: DEFINITIONS OF ANY ADDITIONAL DATA REGARDING SAMPLES ARE ENTERED ON THE FIRST LOG ON WHICH THE DATA APPEAR.

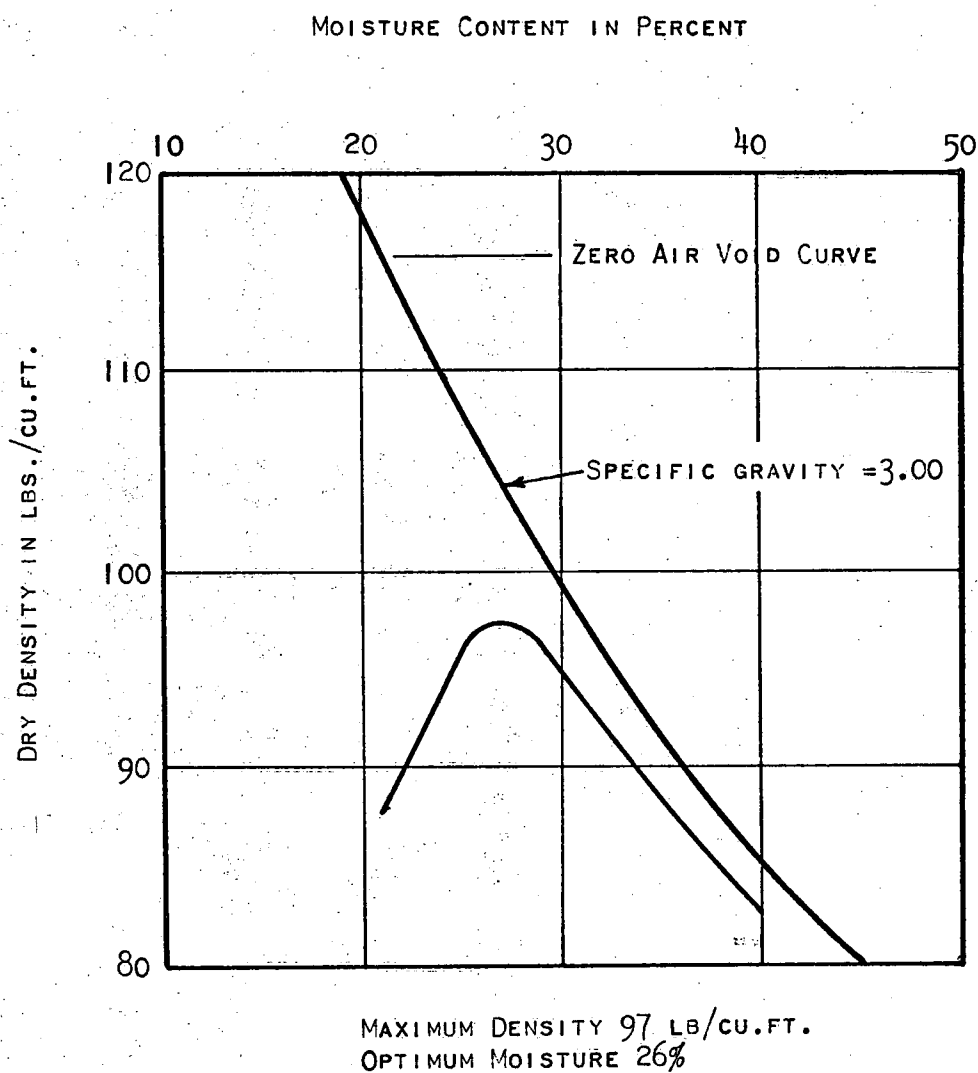
UNIFIED SOIL CLASSIFICATION SYSTEM

BY DATE TO GO  
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BY W. J. [Signature] DATE         
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 REVISIONS         
 FILE 7503-002 BY        DATE       



C O M P A C T I O N   T E S T   D A T A

